

ON THE GEOMETRIC ISOMERS OF ETHYL 2-NITRO-3-ETHOXYACRYLATE, ETHYL 2-NITRO-3-PHENYLAMINOACRYLATE AND ETHYL 2-CYANO-3-PHENYLAMINOACRYLATE

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Abstract—The title compounds exist as mixtures of Z,E-isomers. The assignment of the proton signals of PNMR spectra is performed empirically and by application of lanthanide shift reagents.

In recent years several investigators have found by NMR methods that polarized ethylenes have free energies of activation (ΔG^\ddagger) to rotation around the double bond lower than 25 kcal/mol.¹ The compounds 1-3 exist as mixtures of Z,E-isomers in various solvents (acetone, chloroform and carbon tetrachloride).^{2a,b}

In the present work, the exact assignment of the proton signals has been made by use of lanthanide shift NMR investigations.

RESULTS

The PNMR spectra of the compounds under investigation show two sets of proton signals, because the rotation about the CC-bond is restricted (Table 1).

The assignment of the olefinic proton signals of compound 1 is based on the empirical method proposed by Matter³ and Descotes.⁴

Using this method, the calculated δ -values of 7.94 ppm (Z) and 8.60 ppm (E) give information about the configuration by a comparison of the calculated and observed δ -values. The result indicates that the low field signal should correspond to the E-isomer. An assignment, based on long-range shielding, has been performed in the case of compound 2.

The theories of long-range magnetic shielding suggest that the chemical shift of a proton will depend significantly on the precise spatial relation between the proton and various groups of electrons in its vicinity. Jackman⁵ and Huisgen⁶ demonstrated that in α,β -unsaturated esters the olefinic protons are specifically deshielded by a

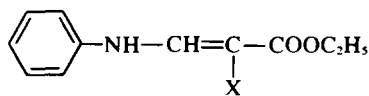
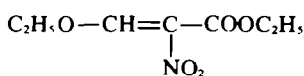
Table 1. Chemical shift data of the compounds 1-3, recorded at room temperature in $CDCl_3$ relative to an internal HMDS standard

Compound	Chemical shift δ , [ppm]				configuration	isomer ratio %
	CH ₃	CH ₂	=CH	NH		
1	1.30†	4.29†	8.19		E	32
			7.50		Z	68
2	1.34	4.34	8.96	10.92	E	48
			8.43		Z	52
3	1.26	4.22	8.27	8.66	E	33
			7.81	10.68	Z	67

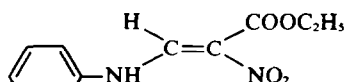
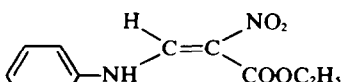
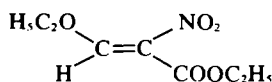
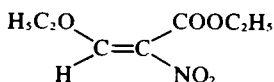
†The average chemical shift δ of the multiplet.

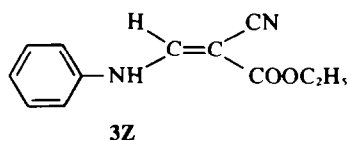
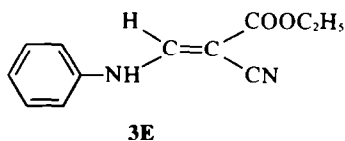
cis-alkoxycarbonyl group. The average values $\Delta\delta$ are in the order of 0.55-0.77 ppm. They are clearly smaller than the $\Delta\delta$ -values of 1.08-1.23 ppm found by Descotes⁷ for the deshielding of the olefinic protons by a *cis*-nitro group.

Consequently, it can be expected that a nitro group in the α -position of the α,β -unsaturated ester should cause a decrease of the differential shielding of the olefinic proton. This difference expected at about 0.5 ppm is in good agreement with 0.53 ppm as observed by NMR. The effects of distant groups on the local diamagnetic shielding is assumed to be equal for both isomers.⁷ In this way, the high field signal of the olefinic proton would be assigned to the Z-form. The low field signal of the NH-proton in compound 3 should correspond to the Z-isomer. An intra-molecular H-bond between NH and



2: X = NO₂
3: X = CN





CO detected by IR is accompanied by this deshielding effect.

To prove the above conclusions we have studied the effect of lanthanide shift reagents (LSR) on the NMR of compounds 1-3. Lanthanide complexes associate with basic functional groups of organic compounds. Magnetic interactions accompanying the association induce shifts in NMR spectra. With lanthanides the predominant magnetic interaction is pseudocontact⁸⁻¹⁰ and the McConnell-Robertson relation¹¹⁻¹³ is used to obtain quantitative geometric information.

In order to perform a configuration assignment, it is necessary to accumulate information regarding preferred sites of complexation. There are three possibilities in compound 1: Ether oxygen, ester carbonyl oxygen and the nitro group. A complexation at the ether oxygen can be ruled out. This assumption is supported by an investigation of ethyl 2-cyano-3-ethoxyacrylate and 2-cyano-3-ethoxyacrylonitrile,¹⁴ where no noticeable complexation occurs at the ethoxy group. The nitro group is very weakly complexed.¹⁵ Only recently produced LSR¹⁶ are able to induce significant shifts in nitro compounds, nitrile compounds and cyclic hydrocarbons. We therefore assume, that at the low concentration of shift reagent used in this investigation coordination takes place at the carbonyl oxygen (Fig. 1).

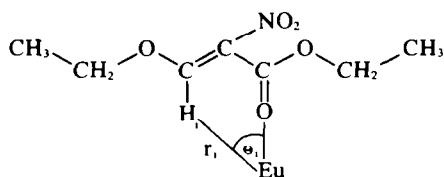


Fig. 1. Model of the Z-configuration of compound 1.

The angles θ , and the distances r , were estimated on the basis of Dreiding models. Several investigations have yielded Eu-O- distances of 3.0-3.5 Å.¹⁷⁻¹⁹ By the method of iterative adaption we have found 2.8 Å to give the best correlation. This value was also chosen for the similar ethyl 2-cyano-3-ethoxy-acrylate.¹⁴ In Fig. 2, the induced shift Δ_i for the protons is plotted against [LSR]/[substrate]. The high field signal of the olefinic proton is shifted to a larger extent than the low field one.

The LIS-parameters calculated from the first straight part of each curve were plotted against $G_i = (3 \cos^2 \theta - 1) \cdot r_i^{-3}$ (Fig. 3). A straight line can be observed for the Z-form of 1, while no correlation is obtained for the E-isomer. We therefore conclude that the more abundant isomer represents the Z-configuration.

The correctness of the assumption that complexation in compound 1 takes place at the carbonyl oxygen is indirectly supported by this result.

Contrary to compound 1, ethyl 2-cyano-3-ethoxyacrylate exists under the same conditions exclusively in the stable E-form, in as much as the linear nitrile group has a smaller steric requirement. In compound 2, there are also three possible sites of coordination. At the low concentration of shift reagent complexation should take place only at the nitrogen of the amino group or the

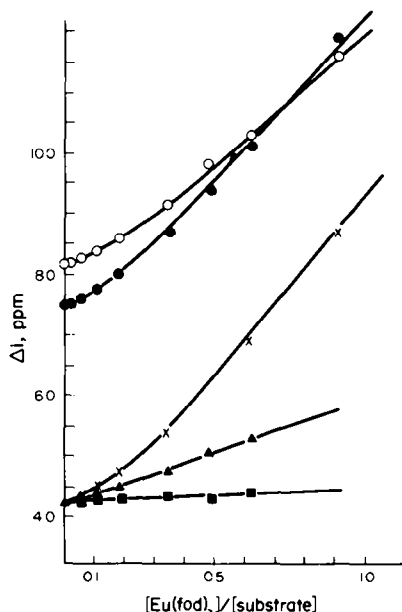


Fig. 2. Plots of the induced shift values Δ_i for compound 1 as a function of the molar ratio $[\text{Eu}(\text{fod})_3]/[\text{substrate}]$. \circ , H_E ; \bullet , H_Z ; \times , $\text{CH}_{2F,Z}$; \blacktriangle , CH_{2F} ; \blacksquare , CH_{2Z} .

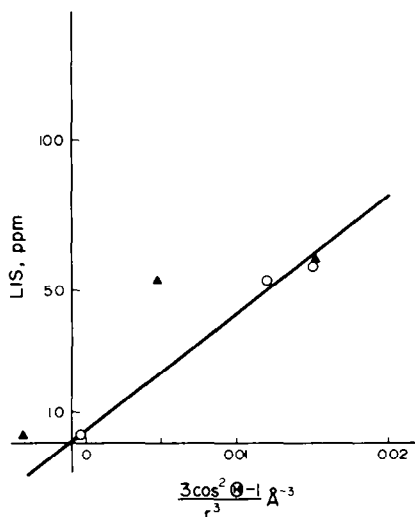


Fig. 3. Plots of the LIS-values for the Z-configuration (\circ) and the E-configuration (\blacktriangle) of compound 1. \circ , Z-form; \blacktriangle , E-form.

carbonyl oxygen. In monofunctional molecules the sequence $\text{NH}_2 > \text{OH} > \text{C}=\text{O} > -\text{O}- > \text{CO}_2\text{R} > \text{CN}$ ¹⁵ shows a decreasing tendency of complexation. The coordination ability, however, of the nitrogen should be decreased by the steric and electronic interactions with the phenyl ring. This assumption is supported by the HSAB-principle.²⁰

In Fig. 4, the induced shift Δ_i of the protons is plotted against [LSR]/[substrate].

The observed results are in good agreement with the above conclusion. The strong shift of the methylene protons at the ethoxycarbonyl group ($\Delta_i \sim 4.5$ and

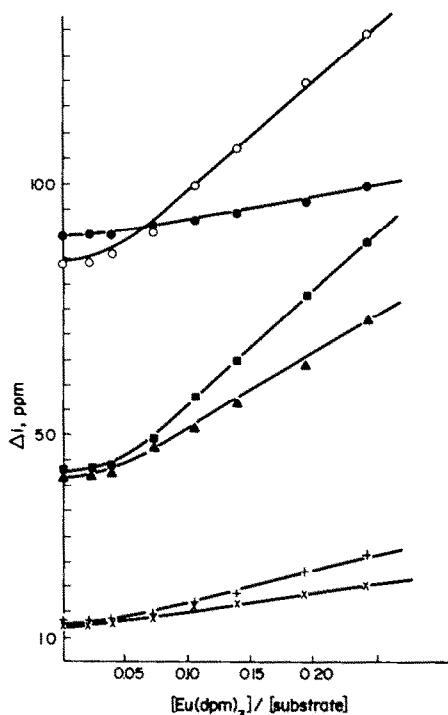


Fig. 4. Plots of the induced shift values Δ_i for compound 2 as a function of the molar ratio $[\text{Eu}(\text{dpm})_3]/[\text{substrate}]$. O, H_Z ; ●, H_E ; ■, CH_{2Z} ; ▲, CH_{2E} ; +, CH_{3Z} ; ×, CH_{3E} .

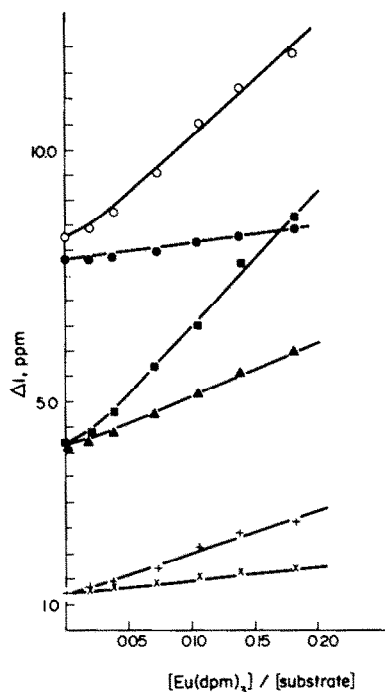


Fig. 5. Plots of the induced shift values Δ_i for compound 3 as a function of the molar ratio $[\text{Eu}(\text{dpm})_3]/[\text{substrate}]$. O, H_E ; ●, H_Z ; ■, CH_{2E} ; ▲, CH_{2Z} ; +, CH_{3E} ; ×, CH_{3Z} .

~3.1 ppm) and the very small influence on the NH and phenyl protons show that the preferred site of complexation is likely to be CO. A coordination at the nitrogen should not be accompanied by a significant Δ_i -difference of high field and low field signals of the olefinic proton as demonstrated in Fig. 4. The high field signal of the olefinic proton, which shifted to a larger extent, must be assigned to the Z-form.

In the case of E-isomer the complexation ability of the ethoxy-carbonyl group is reduced by the influence of the above mentioned NH-CO hydrogen bond. Therefore, the methylene protons of the Z-form are shifted to a larger extent than those of the E-form.

Similar considerations with regard to the site of complexation are valid for compound 3. An investigation into 2-cyano-3-ethoxyacrylonitrile¹⁴ demonstrates that no observable coordination occurs at the cyano group. This finding is supported by the above sequence for the tendency of decreasing complexation.¹⁵ The effect of shift reagent on the NMR of 3 was studied and the results were plotted as before (Fig. 5).

An evident Δ_i -difference of the olefinic proton has been found. The induced shift of the methylene protons is significant ($\Delta_i \sim 4.5$ and ~ 1.8 ppm), while the influence of the shift reagent on the protons of the phenyl ring and the amino group is fairly low. The results predict that the coordination takes place at the carbonyl oxygen.

The low field signal of the olefinic proton is shifted to a larger extent than the high field one. We therefore conclude that the high field signal represents the Z-form. The effect of the NH-CO hydrogen bond on 3 can also be observed. Contrary to 2, the equilibrium of 3 is shifted to the Z-form. The intramolecular hydrogen bond should be one reason for this displacement found by NMR.

While the nitrile group is no proton acceptor in similar compounds,²¹ a hydrogen bond exists between the amino

group and nitro group in 2. This is a competitive reaction to the NH-CO hydrogen bond which should favor the observed compensation of the isomer ratio (48:52%) of compound 2. The synthesis of 3 from the stable E-isomer of ethyl-2-cyano-3-ethoxyacrylate yields predominantly 3Z (90%). This inversion of the configuration would be stimulated by the above mentioned hydrogen bond.

EXPERIMENTAL

NMR measurements. The spectra were recorded on a Varian A-100 spectrometer and a spectrometer TESLA BS 487 C (80 Mc) in chloroform. Chemical shifts are in δ units (ppm) from internal HMDS. The shift reagents $\text{Eu}(\text{fod})_3$ (compound 1) and $\text{Eu}(\text{dpm})_3$ (compounds 2 and 3) were used. After each addition of the LSR the probe was kept for 20 min before induced shifts were determined.

Synthesis of compounds. The compounds 1-3 were synthesized as described in Refs. 2b and 22.

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